30th Annual EAEPE Conference
"Evolutionary foundations at a crossroad: Assessments, outcomes and implications for policy makers"
Nice-France, 6-8 September, 2018

The Network Transformation of Economic Systems Towards Greater Organizational Complexity and Non-linearity

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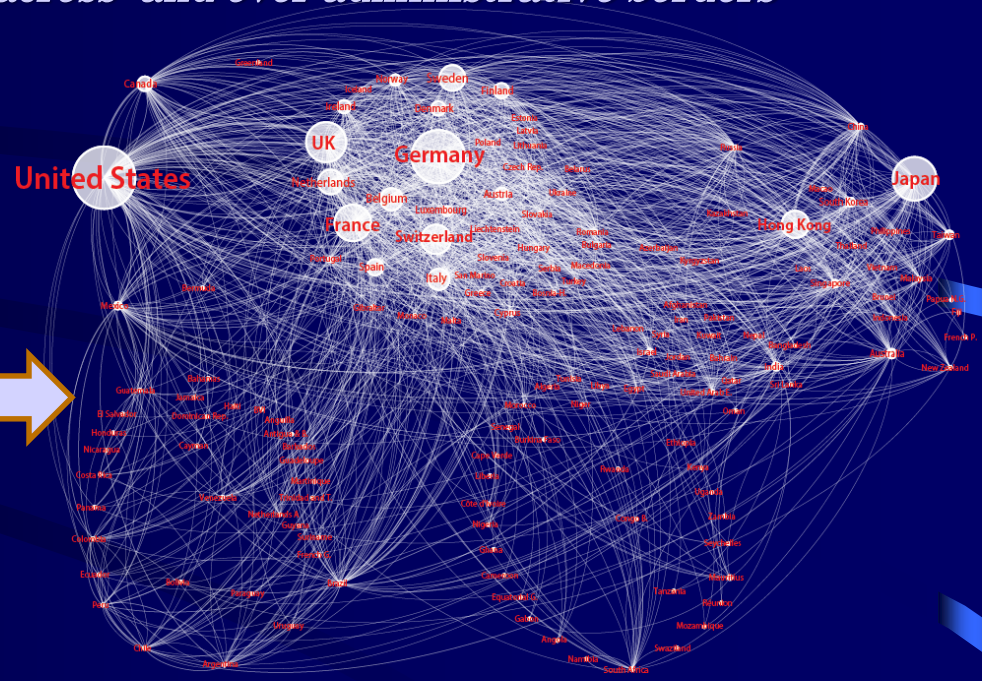
Session
"Complexity Economics and Mesoeconomics: Addressing the Exigencies and Contradictions of today's complex world"

The digital revolution and globalization move the global economy and all its sub-systems towards assuming **a network-based design,** to become agile, self-organized and self-governed ecosystems

Multidimensional economic space emerging across and over administrative borders



The term "ecosystem", while applied in modern economic literature to a broad variety of related phenomena *(business ecosystems, software ecosystems, industrial ecosystems, etc.)*, highlights the increased organizational complexity of economies and the vital role of network interactions in achieving sustainable development *(N. Smorodinskaya. The Globalized Economy: from Hierarchies to a Network Order. Monography. IE RAS, 2015)*

Under the evolving **network economic order :**

- **all economic processes are getting decentralized, dispersed and interactive**, which lends the world *enormous productivity forces* *(Williamson 2005)* that emerge out of leveraging knowledge by firms and individuals in the course of their network communication *(Hidalgo 2015).*
- **all economies are becoming non-linear systems** with an emergent, unpredictable behavior *(Elsner et al., 2014)*, which plunges nations into *unprecedented uncertainty* *(Kidd 2008).*, or into *the complex world of "unknown unknowns"* *(OECD 2015)*

The neoclassical mainstream has no idea on how to achieve resilience and robustness of economies under high uncertainty.

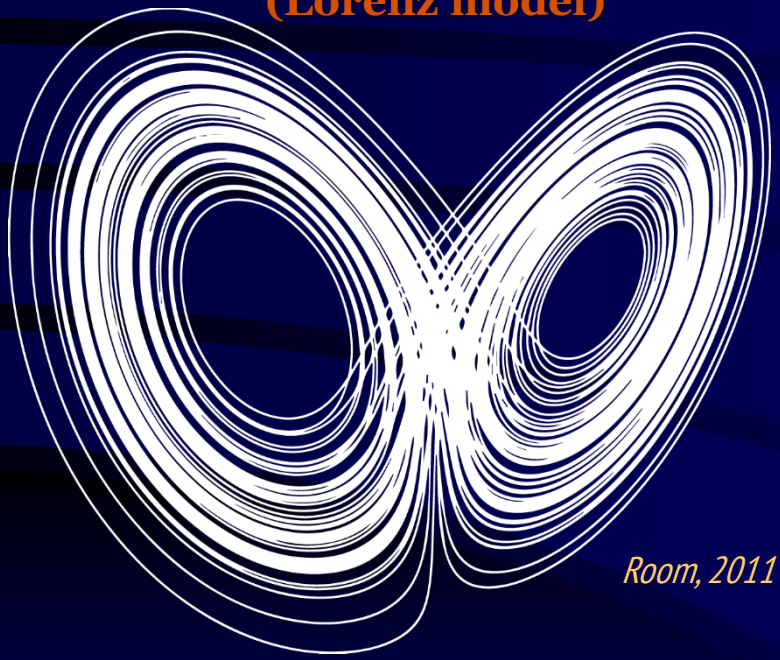
- Therefore, the **OECD initiative "New Approaches to Economic Challenges"** (2015) calls national decision-makers to upgrade their traditional economic thinking and *start viewing economies as complex non-linear systems* that demonstrate novel standards of behavior, getting no longer sensitive to old methods of control.

The new economic thinking, or **complexity economics** paves its way by incorporating approaches of **complexity science** which seeks for **harnessing complexity, and not for eliminating it** *(Axelrod, & Cohen 2000; Beinhocker 2006; Colander, Kupers 2014)*

Complexity economics describes ecosystems (both local and economy-wide ones) through inherent properties of **complex adaptive systems (CAS)**

- CAS are holistic (can't be decomposed into separate parts). They are viewed as ecosystems since they are open networks, where each agent operates in the environment created by its interactions with others, so that the whole network is inseparable from its ecosystem of forward and feedback linkages *(Elsner 2015).*

The traditional image of CAS (Lorenz model)

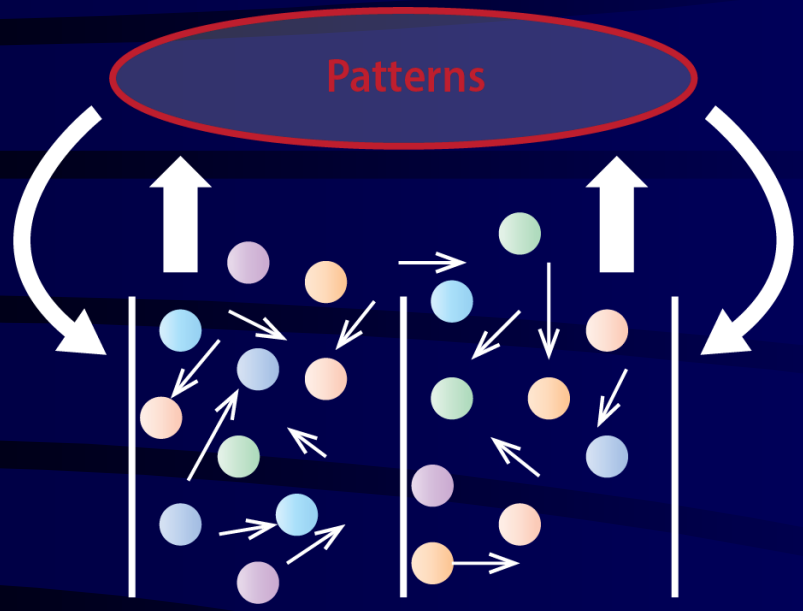


Room, 2011

- Emergence, synergy, adaptability, feedback cycles, self-organization, self-regulation, self-similarity, etc.
- CAS embraces a wide variety of autonomous heterogeneous agents that communicate both in non-linear and interactive ways, continually adjusting their emergent behaviours to behaviours of other agents and to the changing environment through feedback linkages .
- Reflexive self-correcting changes make the economy highly adaptive (resilient) to any internal or external emergencies *(Antonelli 2011; Elsner & Heinrich 2009; Dopfer 2012).*

- **Modern innovation economies need no central governance**. As network ecosystems, they obtain sources for growth and achieve dynamic sustainability endogenously, through persistent structural transformations, thus getting the ability for self-organization, self-regulation and self-development

Ac to CAS theory, in ecosystems, **the aggregate** ("global") **growth pattern emerges spontaneously**, just due to mutual self-adaptation of agents interacting at "local" levels *(Kauffman1995, Al-Suwailem 2011, Schneider 2012)*



Pendleton, 2011

In any ecosystem diverse agents interact chaotically but within its dimensional and institutional boundaries

In the course of interaction, they self-adapt to each other, interlace their trajectories, and start evolve in accordance (co-evolution)

- Co-evolution of agents leads to **a certain structural order**, treated as an aggregate pattern of behavior and growth, generating its own feedback linkages

- The emerged pattern implies that the ecosystem has achieved **a certain level of self-organization** and **state of dynamic sustainability** (equilibrium). Adapting through feedback to this pattern, the agents upgrade their individual behaviours, which moves the ecosystem to **a new level of self-development**.
- **The state of equilibrium is transitive**. In the course of further interactions, **the achieved pattern gets creatively destructed,** which **orients an ecosystem at more diversity and innovation**
- **The same is true for modern economies, which rely on co-evolution of various local ecosystems.**

Harnessing complexity

Complexity economics **views sustainable economic growth as a result of synergies** generated by network interactions between autonomous agents and their groups. Such synergies depend on the very pattern of interactions, which defines the level of complexity of a system *(Martin & Sunley 2007; Silim 2012; Room 2011).*

Modern literature on innovations *(the stream of Lundvall)* assumes that transition of economies from systems to ecosystems lays organizational foundations for their transition to innovation-driven growth.

- New values are now co-created interactively through collaboration of networked agents that develop an ecosystem of linkages,, or just *an innovation ecosystem* *(Lundvall et al. 2009; Mercan & Göktaş 2011).*
- National innovation systems can't be intentionally designed by governments. Rather **they emerge as complex ecosystems in a bottom-up way,** through myriad varieties of interactions among diverse agents *(Wessner and Alan, 2012)*

Modern literature on competitiveness *(the stream of Porter)* directly connects economic growth with **innovation synergy effects achieved through collaboration** *(Porter et al. 2008).*

- Collaboration is seen as the highest form of interactive cooperation when partners develop shared vision, common identity, shared rules (joint responsibilities), and tools for value co-creation *(Camarihna-Matos, Afsarmanesh, 2008)*
- The deeper is collaboration within an ecosystem (or ecosystem-based economy), **the greater is its innovation potential for growth** *(Porter 1985; Rullani 2002; Solvell 2015).*

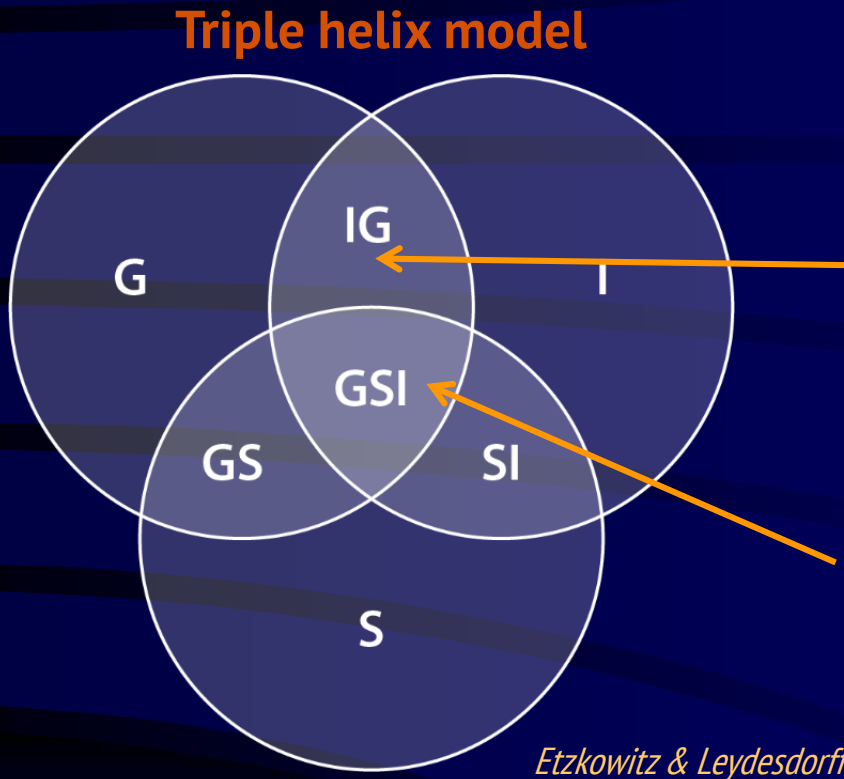
Harnessing complexity implies leveraging ecosystemic innovation *(Russel & Smorodinskaya 2018)*

In an innovation ecosystem, collaborating partners rely on relational contracts (defining long-term rules of the game) and on building mutual trust. As a result, they can creatively reshuffle (assemble and reassemble) their individual assets, knowledge and skills in numerous novel and complementary ways.

- **The emerging synergy effects multiply the productivity of individual assets** *(Delgado, Porter, Stern 2010)* and enable the partners to co-create innovative products and values continually, thus self-adapting to rapid changes in technologies and market demands *(Smorodinskaya 2015)*

Creative and complementary reshuffling of shared assets in a cluster ecosystem *(Sölvell 2009,)*

The most sophisticated pattern of collaboration is known as Triple Helix Model – a **fractali-type co-evolution of three functionally different agents or their groups**



G - government, I – industry (businesses), S - science (universities)

Collaboration externalities of pairwise co-evolution *(reduction of costs, reduction of uncertainties, escaping technological lock-ins)*

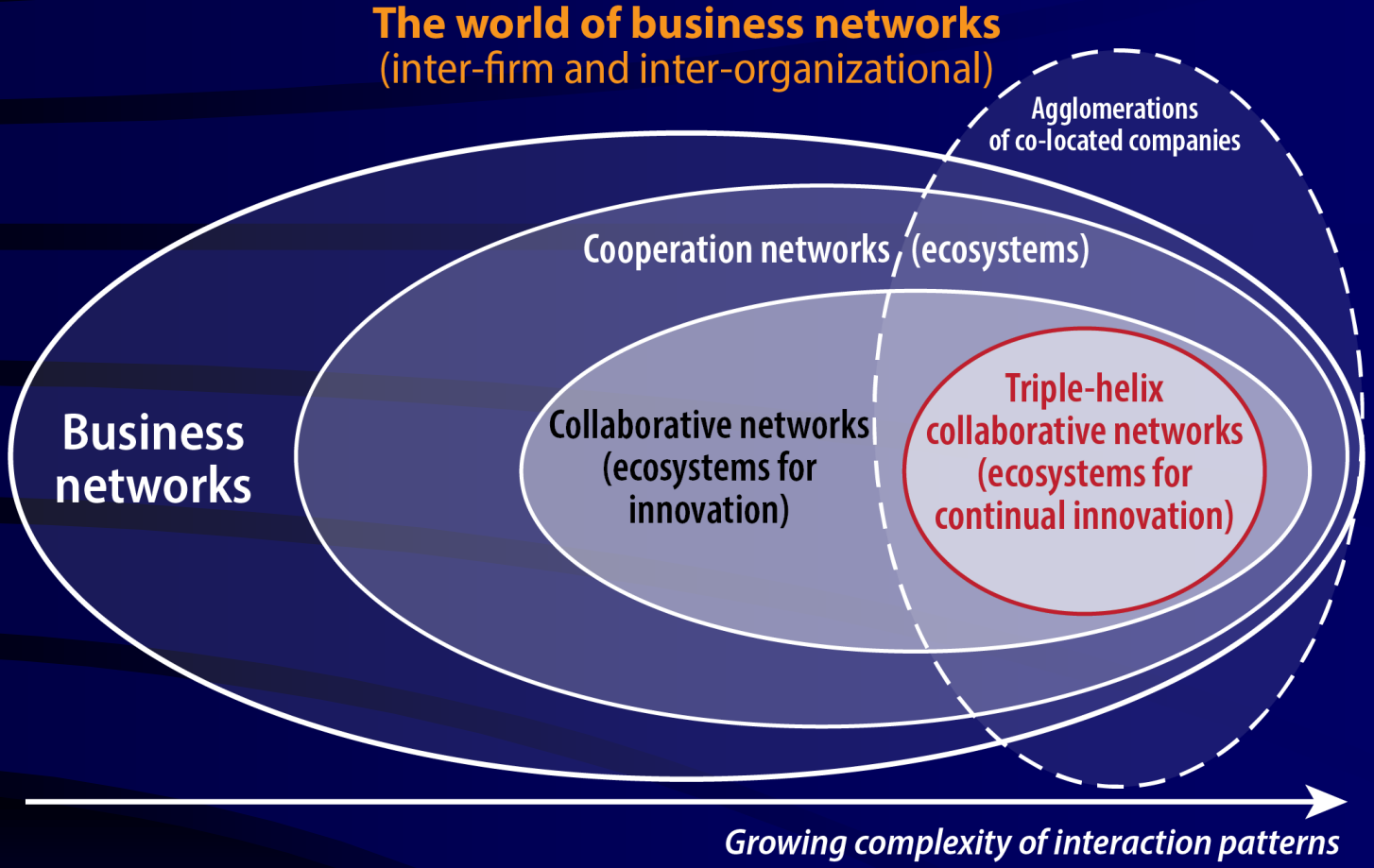
Aggregate collaboration synergy effects: sustainable motivations both for co-creation of new goods and values continually *(leading to a continual productivity growth)* and for collective self-regulation *(collaborative governance)*

Etzkowitz & Leydesdorff 2000; Ye, Yu, Leydesdorff, 2013

Formalization of the triple helix model shows that it generates very sophisticated functional interdependences and feedback linkages, which lends the system **the capacity for self-sustained growth.** New sources of growth emerge endogenously through internal structural changes

- innovation dynamics of economic systems, and hence, their ability for sustainable growth are proportional to their complexity *(Ivanova, Leydesdorff, 2014; Ye, Yu, Leydesdorff, 2015)*

On this basis, we classify the world of business networks according to their innovativeness



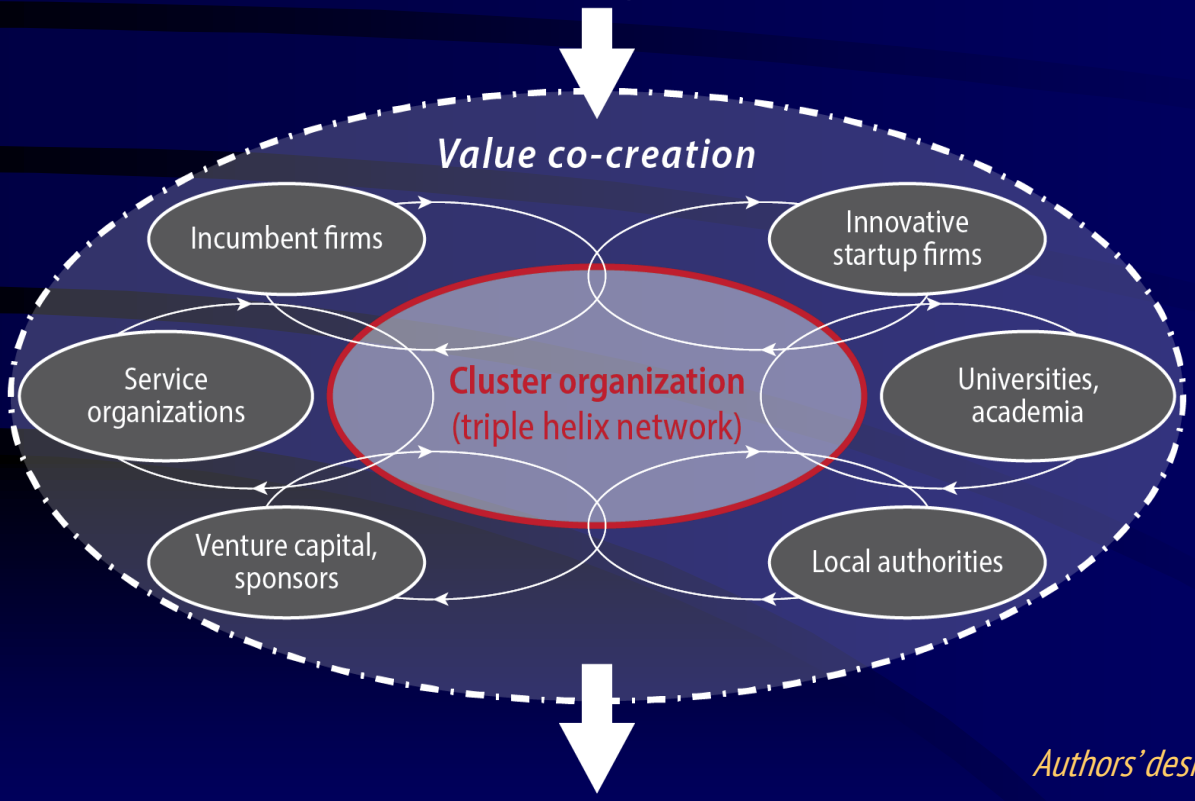
Russel & Smorodinskaya. Leveraging Ecosystemic Innovation. "Technological Forecasting and Social Change". February 2018

Networks with a higher complexity in the interaction pattern are supposed to generate greater innovation synergy effects. Ecosystems generated by just cooperation networks have lower innovation potential than ecosystems generated by collaborative networks, while ecosystems with a more sophisticated, triple helix pattern of collaboration will be more innovative that those where Triple Helix relationships are not developed.

Regional innovation clusters are a prevailing model of triple-helix partnerships for sustainable growth, generating synergies both for a continual innovation and for a collaborative governance

- Clusters are open-end networks of autonomous, geographically co-located and functionally diverse agents that collaborate within a common project coordinated by a specialized cluster organization

Ecosystem of innovation cluster



Key participants:

- *Representatives from three institutional sectors* – business, government, academia
- *Cluster organization* – membership-based internal network of triple-helix actors, acting altogether as a project coordinator

Triple helix implies co-evolution of three actors in a cluster and co-evolution of three institutional sectors in an ecosystem-based economy

Authors' design based on TCI 2013, Napier & Kethelz, 2014

Micro-, meso-, and macro-levels in decentralized network-based economies

- In ecosystems, different levels of activity have transcended boundaries and dynamically interact with each other. Autonomous agents communicate directly within and across various levels, thus building equal **"micro-foundations"** throughout the economy.
- While developing an ecosystem of micro-linkages, agents start co-evolving and coordinating their decisions through self-organization into groups, thus shaping various sub-systems of the economy, which could be seen as **meso-economic level.** Co-evolution of meso-level sub-systems generates synergies out of which the **macro-economic pattern** emerges.

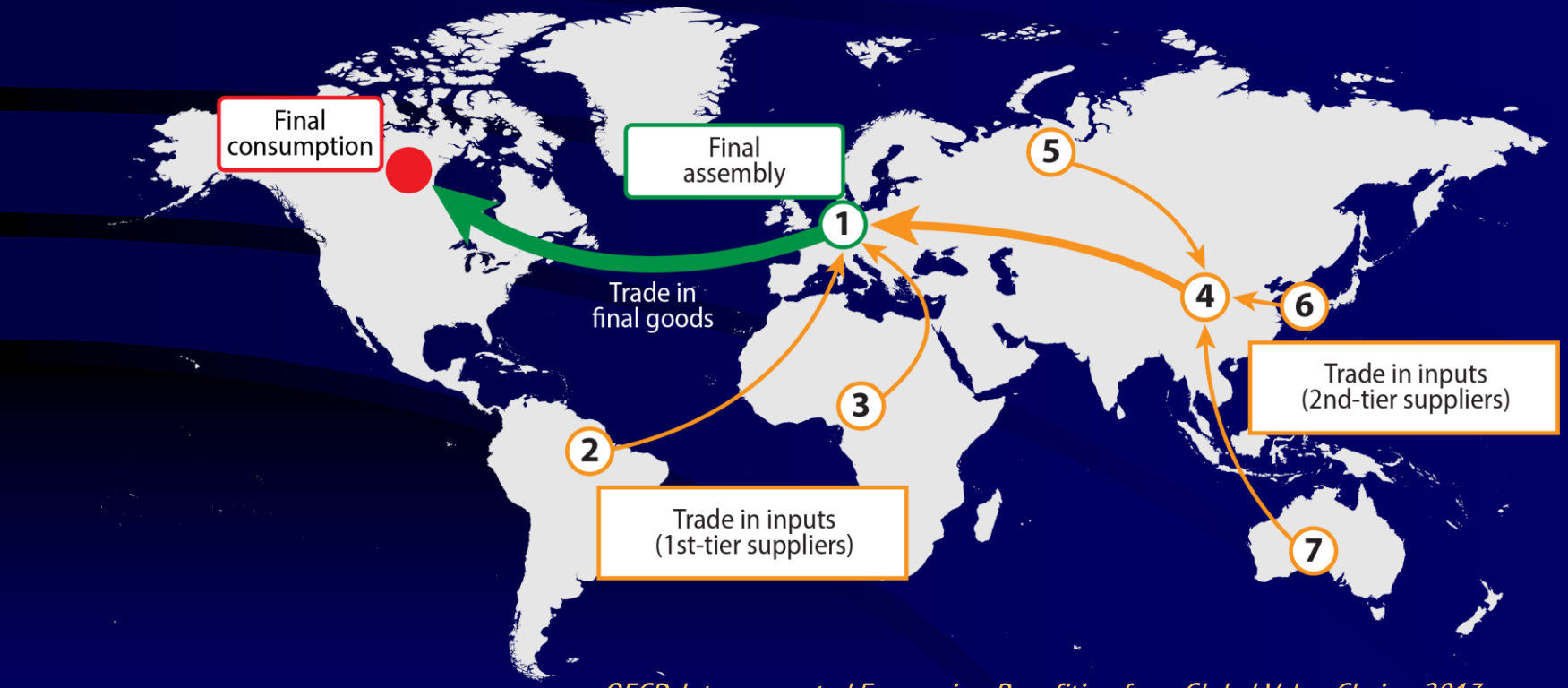
Relying on findings from complexity literature *(Kauffman 1995, Haken 1988, Elsner 2009, Room 2011, Dopfer 2012, Dosi 2013, Sawyer 2018, etc)*, we identify **meso-level in a modern economy**:

- with various localized ecosystems, or sub-systems, where interacting agents display a certain pattern of integration and collective behaviour. F.e., *innovation clusters* are specialized meso-level sub-systems of both national economies and the globalized system of production through global value chains.
- with a transition phase at which sub-systems achieve a certain state of equilibrium or certain dynamic balances *(between chaos and order, cooperation and competition, homogeneity and heterogeneity, specialization and diversification, local and global level of integrity, micro- and macro-level of performance*). In this way, complex economies are becoming **transformative multi-equilibrium systems.**
- with the stabilizing role of multiple network nodes, through which a dispersed and transformative economy coordinates itself, shaping and reshaping its structural design

The increased complexity of production process under globalization

- Production process gets geographically and functionally dispersed, as well as increasingly interactive and project-based. New final goods are co-created within **global value chains (GVCs)** through collaboration of numerous companies from different countries *(Baldwin 2009;, OECD 2013; Gereffi 2014; Loss, Timmer , deVries 2015)*

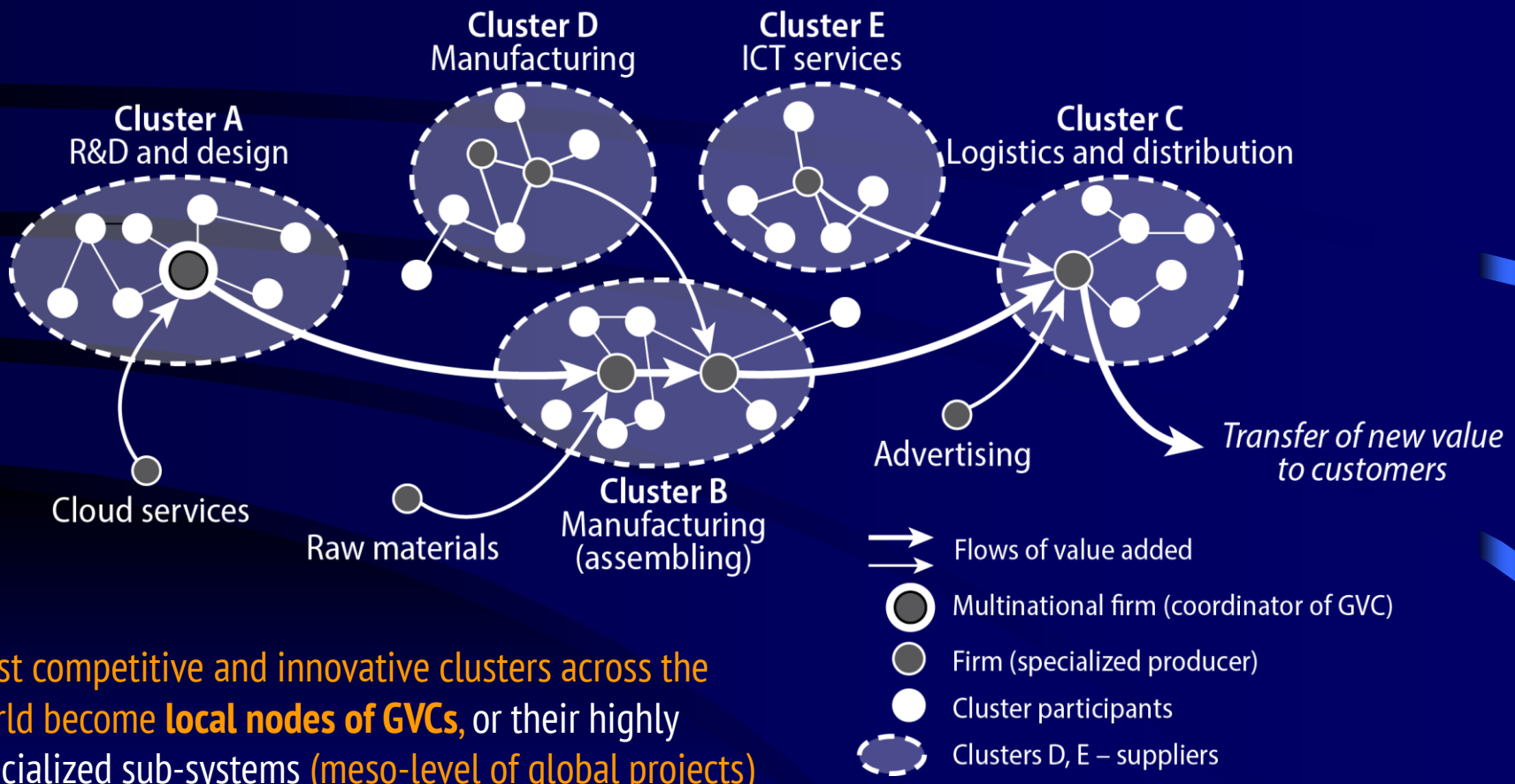
The modern production and trade system is a very complex system of global circulation of resource flows that generate numerous forward and feedback linkages *(Hudson 2004, OECD 2012)*



OECD. Interconnected Economies: Benefiting from Global Value Chains, 2013

In terms of design and complexity, **GVCs are dispersed project-based ecosystems, where numerous legally independent firms collaborate interactively to co-create a new final product**

- Each firm realizes a unique business-task in the common project, usually belonging to a certain regional cluster. The lead firm (organizer of the GVC) acts as **a coordinator,** enlarging the total income in the GVC through continual enhancement of forward and feedback linkages between project partners



- Most competitive and innovative clusters across the world become **local nodes of GVCs,** or their highly specialized sub-systems (meso-level of global projects)

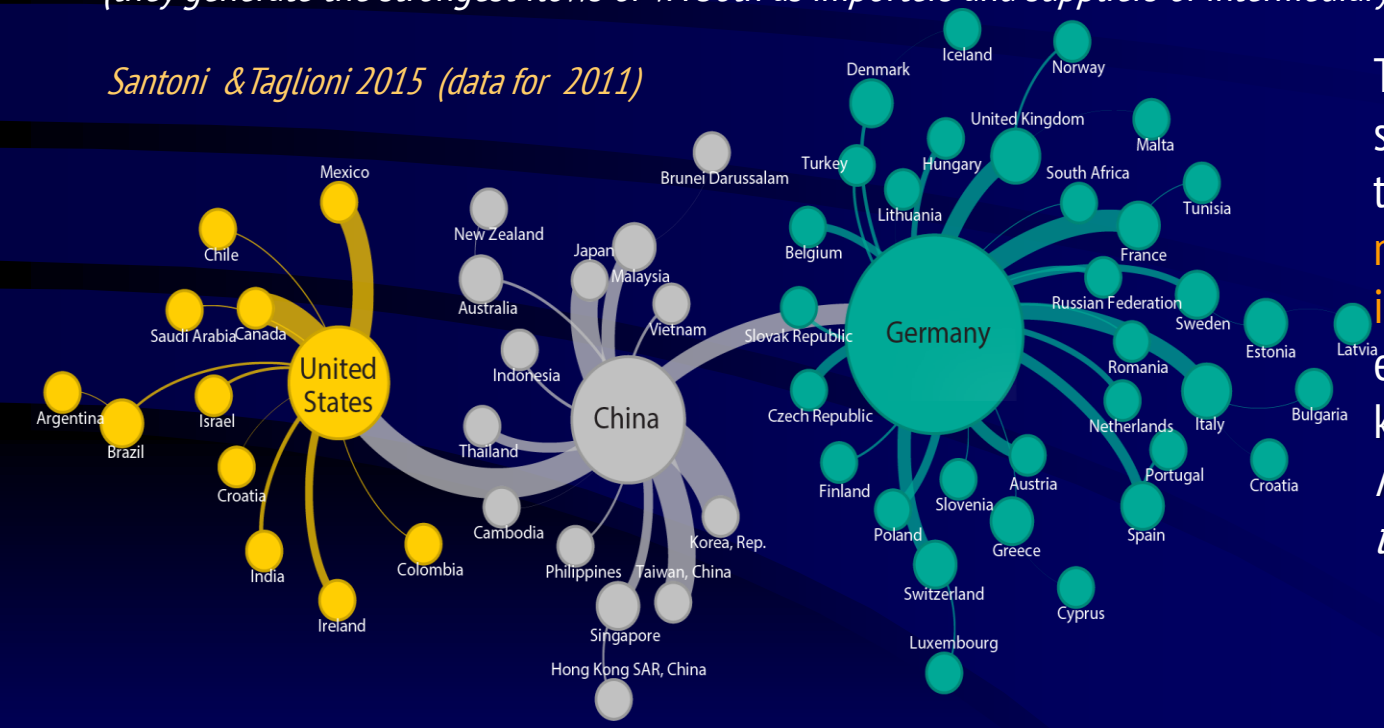
Smorodinskaya & Katukov. Dispersed Production. "Economic Policy". 2017, #6

The world economy is transforming itself into a multi-equilibrium global ecosystem embracing a combination of sub-systems of various scale, design and complexity *(Room 2011, Silim 2012, OECD 2015).*

A key example of meso-level sub-systems are **dispersed "factories" in North America, Europe and Asia - three powerful macro-regional ecosystems,** self-organized through geographic and functional overlapping of different **GVCs** (inter-firm networks)

US, Germany and China are main country-level nodes of world production and trading through GVCs *(they generate the strongest flows of VA both as importers and suppliers of intermediary products)*

Santoni & Taglioni 2015 (data for 2011)



Two other kinds of meso-level sub-systems are evolving in the form of global production networks **(GPNs)** and global innovation networks **(GINs)** - ecosystems meant for knowledge exchange *(having more sustainable linkages than project-shaped GVCs)*

Parrilli, Nadvi, Yeung 2013

- **A 'factory world' is emerging:** the world economy is assuming a glocal pattern of self-organization, becoming both globally dispersed and locally specialized *(Coe, Yeung 2015; OECD, World Bank 2009)*

Comparison of traditional (neoclassical) and complexity thinking of innovation and growth

	System approach (traditional thinking)	Ecosystem approach (complexity thinking)
Economic dynamics	Linear systems –– closed, static, in equilibrium. Agents interact indirectly through price signals	Non-linear systems –– open, dynamic, dissipative. Agents interact directly within networks
Macro-level growth pattern	Formed by summation of individual decisions of homogenous agents, no synergy effects	Emerges out of synergies generated by interactions of heterogeneous agents at local (micro and meso) levels
Model of governance and capacity for adaptation	Hierarchic model with top-down administrative decisions. Lack of feedback linkages, low capacity for adaptation	Heterarchical model with a bottom-up self-organization and collaborative governance. Key role of feedback linkages and interactive communication to make the system self-adaptive
Model of production and innovation	Within national production chains, based on linear models of innovation	Production is a globally dispersed process, based on interactive co-creation of innovations through collaboration of networked agents *(production 2.0)*
Innovation capacity	Limited, requiring external incentives or exogenous sources	Endogenous, arising from self-correcting structural changes in the system
Innovation systems	Non-cohesive structures with a certain mass of agents and new infrastructure	Holistic ecosystems with CAS properties, depending on interactive inter-linkages among networked actors
Business context for innovation	Not considered. Priority is to create new institutions, technologies and industries	Priority is to continually improve environment for self-emergence of more collaborative networks and smooth knowledge spillovers across and around the economy
Focus of growth strategies	To develop R&D and national innovation system by supporting its agents and infrastructure elements	To promote localized ecosystems across the economy and enhance their innovation synergy effects by facilitating collaboration within-between networks

Adapted from: Russel & Smorodinskaya. 2018

Conclusions and policy implications

1. Modern economies tend to become **multi-level, multi-nodal and multi-equilibrium ecosystems** comprised of overlapping business networks that collaborate within and among each other *(MacGregor & Carleton 2012; Smorodinskaya et al., 2017)..* This transformation enables them to achieve self-sustained growth under high uncertainty.

2. Unlike the global economy , at the level of nations, the ecosystemic transformation of industrial landscapes is not automatic but rather requires broad structural reforms. (especially given the inherited hierarchic regimes of the past).

3. This prospect implies pro-active and new role of governments, acting as a facilitator and coordinator of collaborative networks. *(instead of being a supreme supervisor or a night watchman)*

4. National development strategies should now focus on promoting *a socially cohesive and innovation-conducive economic context,* to ensure a continual knowledge spillovers across industries and territories *(Smorodinskaya & Katukov, 2017)*

Thank you for your attention!

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